Tiny Nanoparticles
—A Big Battlefield Impact?

Donald Kennedy

Tiny metallic nanoparticles have the potential to change the landscape of defense technology, from obscuring warfighters from view to providing transparent displays in aircraft and vehicles. A nanoparticle is defined as a particle with one or more dimensions measuring 1 billionth of a meter (1 nanometer [nm]). Typical nanoparticles range from 1 to 1,000 nm. A typical human hair is about 90,000 nm thick. Therefore, an item of 1 nanometer would be invisible to the naked eye.

Scientists at the U.S. Army Edgewood Chemical Biological Center (ECBC), the Massachusetts Institute of Technology's Institute for Soldier Nanotechnologies (MIT-ISN) and the Harvard University Department of Physics are using nanoparticles to develop a novel transparent display technology and improve the design of obscurants, which are used to generate smoke that can hide a warfighter from plain sight.

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Improved navigational imagery and information displays on various surfaces are just some of the battlefield uses that may be available to warfighters. Imagine an Air Force pilot using a map projected on his cockpit windshield to safely navigate to a location or soldiers in the field who are in turn digitally displaying information on an armored vehicle window. Through ECBC's In-House Laboratory Independent Research (ILIR) program, ECBC researchers are able to collaborate with the MIT-ISN on various projects such as the transparent display technology, which explores how particles scatter and absorb light efficiently.

Typically, when an image is projected onto a transparent material such as glass, it simply goes through the glass, and the image cannot be viewed. By coating the glass with a polymer that contains silver nanoparticles with the appropriate size, images can be reflected back and viewed as if they were on a screen. Additionally, the transparency of the glass is retained. Advantages of this technology also include a wide viewing angle and the ability to scale the materials onto large display areas.

Each of the silver nanoparticles used in this technology is designed to scatter or reflect one color while rejecting the rest. Although the current technology displays blue light successfully, researchers are working to implement red and green displays in the future. In order to achieve new colors, researchers will have to control the size, shape and composition of the nanoparticles across scattered light. Currently, a silver particle is used for scattering and imaging blue light. In order to simultaneously scatter multiple colors of light, researchers can use three different nanoparticles to scatter three different colors of light, or they can create a clever particle with the correct properties that enable the display of all three colors.

Brendan DeLacy, an ECBC researcher in the Toxicology and Obscurant Division, continues to work with MIT-ISN on the transparent display but is also pursuing how nanoparticles can enhance obscurants, concealing the location of a warfighter from plain sight. Recent design upgrades can now hide a warfighter from infrared and other sophisticated types of viewing, thanks to a range of metallic nanoparticles including gold and silver that enhance the attenuation of light in a given region of the electromagnetic spectrum. This type of obscurant work is especially important in improving defense in theater, as particles are used to absorb or scatter light in order to block a warfighter's visibility over several bands of light.

"The work on the nanoparticles in obscurants is closely related to the development of the transparent display technology. It's such a great opportunity to be able to work with MIT and Harvard to develop this type of technology that could make an impact across so many different disciplines," said DeLacy.

The next step in obscurant development will be to fabricate the nanoparticles in large quantities and disseminate them efficiently, so that the aerosolized particles retain their optical properties. Scientists at ECBC have made significant efforts to design and fabricate metallic particles with an ideal shape and composition for maximum obscuration.

"In our obscurants project, MIT provides computational models that predict the optimum size and shape of nanoparticles that are required to absorb and scatter light. ECBC is responsible for creating the particles that are predicted by those models," DeLacy said.

Silver and gold nanoparticles have been extensively studied for their unique optical properties which arise from localized surface plasmon resonance (LSPR). This resonance results in a very strong attenuation of light in the visible and near-infrared regions due to the strong enhancement of the local electric field both inside and near the surface of the particle. LSPR is the resonance between the collective oscillation of conductive electrons and the incident light. This phenomenon has been employed in chemical and biological detection techniques such as surface-enhanced Raman scattering and enhanced fluorescence spectroscopy. The size and structure of the silver and gold nanoparticles have a significant impact on LSPR, which can affect sensors and photonic devices.

An additional application of plasmonic nanoparticles is their use in tagging, tracking and smart bar code applications. For example, gold nanoparticles coated with an alkanethiol can be deposited and printed onto paper, plastic or cloth, with a specific circuit pattern. The circuits form radio frequency identification (RFID) tags and can be used in security applications to identify a given material as a friendly or enemy force.

Metal oxide nanoparticles, which have also been explored as potential obscurants, have alternative military uses, including their ability to react with and destroy chemical and biological warfare agents. Nanocrystalline metal oxides are

Using nanoparticles, an image of a blue MIT logo is superimposed on a glass screen. The cups are physical objects behind the screen.
MIT News photo.

semiconductors that are activated upon interaction with light. Once activated, the metal oxide nanoparticles act as both acids and bases, and bind efficiently to chemical and biological agents, thereby converting the hazardous material to safer byproducts. *[Editor's Note: For medical and biological warfare applications, see the preceding article in this issue.]*

According to recent studies and papers on nanoparticles, the tiny structures could have big implications in the biomedical field. Some investigations explore how magnetic nanoparticles potentially could be injected into the body to detoxify people who might have been exposed to poison gas. The magnetic particle would bind to the toxin and literally drag it out of the body. Other biomedical projects include the possibility of using gold nanoparticles as a replacement for chemotherapy in cancer patients.

While ECBC and MIT-ISN have not pursued all of these types of nanoparticle applications, there is a vast field of possibilities. ECBC and MIT-ISN continue to develop the design and fabrication of improved obscurants, and also the transparent display technology. Nature Communications recently published an article, "Transparent Displays Enabled by Resonant Nanoparticle Scattering," which describes the work being done toward transparent display technology.

MIT-ISN serves as one of the U.S. Army's University Affiliated Research Centers. This status means that the Army funds these university centers to research and develop new technology for military uses. The research for this project was funded by the U.S. Army Research Office and by the National Science Foundation.

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